Light to PWM converter

Technical Field:

Embodiments in accordance with the invention relate generally to optical to electrical converters. More particularly, the invention relates to optical to digital converters.

Background:

Many devices require the conversion of optical properties such as intensity to an electrical signal. Common solutions to the conversion problem use conventional analog to digital converters where an analog input from a sensor such as a photodiode is supplied to a analog to digital converter (ADC) which produces a multi-bit digital output representing the intensity level of the input signal. Implementations of such a solution require careful attention be paid to layout and signal paths. Analog signal conditioning is required between the photodiode and the analog to digital converter. A stable reference voltage must be supplied to the analog to digital converter, as well as a conversion clock. All this circuitry takes up space, and costs money.

Summary:

In accordance with the invention, a light to PWM converter is provided. Photocurrent from a photodiode is converted to a voltage by an amplifier such as a transimpedance amplifier. The output voltage of the amplifier representing light intensity is fed to one input of a comparator. A sawtooth generator feeds the other input of the comparator. The digital output of the comparator is a pulse width modulated signal, the pulse width proportional to light level. The sawtooth generator may be synchronized to an external source.

Brief Description of the Drawings:

The invention will best be understood by reference to the following detailed description of embodiments in accordance with the invention when read in conjunction with the accompanying drawings, wherein:

Fig. **1** shows a block diagram of a light to PWM converter according to the present invention,

Fig. **2** shows waveforms of the invention, and

Fig. **3** shows a second embodiment of the invention..

Detailed Description:

The invention relates to light to digital conversion. The following description is presented to enable one skilled in the art to make and use the invention, and is provided in the context of a patent application and its requirements. Various modifications to the disclosed embodiments will be readily apparent to those skilled in the art, and the generic principles herein may be applied to other embodiments. Thus, the invention is not intended to be limited to the embodiments show but is to be accorded the widest scope consistent with the appended claims and with the principles and features described herein.

With reference now to the figures and in particular with reference to Fig. **1**, photodiode **100** converts light to photocurrent **105**. This small photocurrent is converted to a voltage by transimpedance amplifier **110**. Transimpedance, also known as transresistance, amplifiers are well known to the art, for example, "The Art of Electronics" second edition by Horowitz and Hill, pp. 79, 184, 235, 962, 1039. The output voltage **115** of transimpedance amplifier **110** is provided as one input to comparator **130**.

Sawtooth generator **120** provides sawtooth waveform **125** as the other input to comparator **130**. The output of a sawtooth generator ramps from a first low voltage to a second peak voltage, resetting quickly to the first low voltage. Sawtooth generators are well known to the art, typically comprising a current source charging a timing capacitor until a threshold voltage is met, at which point the timing capacitor is discharged. In an ideal sawtooth waveform, the voltage ramp is linear, and the reset time very short. Sawtooth generator **120** also has optional synchronization input **122**. This input may be used to synchronize the sawtooth waveform generated to external signals.

Comparator **130** compares sawtooth waveform **125** with reference voltage **115** representing light intensity detected by photodiode **100**. The output **140** of the comparator is a digital signal. The output of the comparator is high when reference voltage **115** is higher than sawtooth waveform **125.**

This is shown in Fig. **2**. Line **115a** shows a voltage representing a high light level. Waveform **125** shows the sawtooth waveform from sawtooth generator **120** of Fig. **1**. The period of sawtooth generator **120** is shown as **128** in Fig. **2**. PWM waveform **140a** represents the resulting pulse width modulated output of comparator **130**. The pulse width of this waveform is shown as **150a**. The output of comparator **130** is high when input **115a** to comparator **130** is higher than sawtooth waveform **125** from sawtooth generator **120**. Line **115b** shows a voltage representing a low light level. When compared to sawtooth waveform **125**, PWM waveform **140b** results, its pulse width represented by **150b**. As voltage **115** increases, representing increasing light intensity, the pulse width of output signal **140** increases. The linearity of this response depends on the linearity of sawtooth generator **120**.

As shown, the on-time of the output waveform is proportional to the input light level. By reversing the inputs to the comparator, or inverting the output of the comparator, a signal in which the off-time of the output waveform is proportional to the light level is generated.

While the invention may be implemented in discrete components, it may be implemented in integrated form with all components on a common substrate. This

can result in a three or four pin module, with ground, positive supply, PWM output, and optionally sawtooth synchronization input. This integration need not be in the form of a single integrated circuit, but may be an intermediate form such as packaged or unpackaged components on one or both sides of a substrate. Depending on the size of the timing capacitor used in the sawtooth generator, one or more pins may be provided for allowing this component to be located external to the substrate. In an alternate embodiment, the processing components, all but the photodiode, may be integrated into a single package, connecting to an external photodiode.

In use, the spectral response of the system is determined by the photodiode and the optical properties of its packaging. In many applications, it may be desirable to shape the spectral response of the photodiode by placing optical filtering material in the optical path.

Fig. **3** shows an embodiment using three sensors according to the present invention. Red filter **110** filters light to sensor **112** producing red PWM output **114** proportional to the level of red light. Green filter **120** similarly filters light to sensor **122**, which produces green PWM output **124**. Blue filter **130** filters light to sensor **132**, which produces blue PWM output **134**. Also shown is optional synchronization line **140**, causing sensors **112**, **122**, and **132** to produce synchronized PWM output signals. Depending on the details of the implementation, synchronization may be provided through applying a synchronization pulse as previously described, or may be obtained by driving the comparators in the group of sensors from the same sawtooth generator.

The foregoing detailed description of the present invention is provided for the purpose of illustration and is not intended to be exhaustive or to limit the invention to the precise embodiments disclosed. Accordingly the scope of the present invention is defined by the appended claims.